FERMILAB-LU-233

Determination of the Physical Dimension of the Upgrade Linac LU-233

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1 Definition of the Physical Dimension

"Physical Dimension" in this paper is mainly the longitudinal dimension which is used for calculation of the particle dynamic (e.g.beam emittance measurement etc.), and Δt and phase scanning measurement. That is said:

(1) The tank dimensions and the dimensions relative to the tank are measured from the entrance or exit of the drift tube.

(2) The lengths of quardrupoles, deflection magnet and the dimensions relative to them are measured from their effective edges.

(3) The drift distances relative to the detectors used in Δt measurement are measured at the middle of the wall current monitor or at the front edge of the beam position monitor individually.

(4) The drift distances to the wire scanning and beam length monitor should be relative to the filament ejecting the secondary electrons.

All the dimensions are given in the unit of mm.

2 The Requirement of Accuracy of Positioning and Measurement

The general requirement to the accuracy of positioning and measuring should be as follows:

(1) Transverse position.

Tank: $\lesssim \pm 0.05$ mm.

Quardrupole magnet: $\lesssim \pm 0.05$ mm.

Deflection magnet: deviation angle between beam axis and the normal to the front face of magnet $\lesssim \pm 5 \times 10^{-4}$ (for $\Delta p/p \sim \pm 0.1\%$).

Monitor: $\lesssim \pm 0.5$ mm.

(2) Longitudinal position.

Tank: $\lesssim \pm 0.05$ mm.
Monitors for Δt measurement use: $\lesssim \pm 0.5$ mm.
Quardrupole magnet and focusing drift length: $\lesssim \pm 5$ mm.
Deflection magnet: $\lesssim \pm 8$mm.

3 Calculation Method of the Dimension

(1) Dimension relative to the tanks: Since the accurate distance between the edge of drift tube and the edge of tank geometry is not known, it is assumed that all this distance equals 21.65 mm.

(2) Dimension relative to the quardrupole magnets: The effective length of the quardrupole of upgrade linac is 85.3 mm (the geometric length is 70 mm); of the 400 MeV transport line is 297 mm (geometric 254 mm).

(3) Dimension relative to the deflection magnet: The distance between the effective edge and geometric edge of deflection magnet is 28.5 mm. But the dimension relative to the steering magnet is measured from the geometric edge, because the magnetic field of steering magnet is deformed by the neighbouring quardrupole magnet.

(4) Dimension relative to the wire scanning: The longitudinal distance between the two wires is 10.2 mm. The dimension to the scanner is given to the middle of X and Y scanning wires, which is 13.9 mm from the downstream edge of the box, or 24.19 mm from the upstream edge. Thus the errors of X and Y scanning wires are ± 5.1 mm individually.

(5) Dimension relative to the wall current monitor: Before mounting the distance,d, between the middle of monitor and the valve flat spot was measured. The data of d given by Mr.Owen are as follows:

Monitor	WC14	WC24	WC34	WC44	WC54	WC64
Ref.point at valve	1-UPST	2-UPST	3-UPST	4-DNST	5-DNST	6-DNST
d (mm)	110.94	123.97	143.68	227.39	232.65	260.77

We have no datum about the wall current monitor WC74. It is calculated by the survey data of the outside dimension of the wall toroid UPST and DNST face, and assume the monitor center was at the middle of the outside dimension. This may have an error of about a couple of mm.

(6) The distance between the front edge of BPM of upgrade linac and the survey reference point of the BPM top pin is 3.96 mm in downstream direction. For the BPM-3 in the 400 MeV transport line , it is 140.46 mm in upstream direction.

4 About the Survey Data

We will discuss some possible errors in survey data.

The essential dimension of the tank was given three times. The first was measured on Feb.1992 before mounting on axis [1]. The second was measured in August after mounting [2]. The last was based on the second results and corrected by the change in the temperature of tank.The increase in module length, ΔL, at the third times is as follows:

Module	1	2	3	4	5	6	7
ΔL (mm)	0.99	1.65	1.04	0.74	0.99	1.47	1.27

The increase in total length from the entance of Mod.1 to the exit of Mod.7 is 8.61 mm. The question is what is the accuracy of the data given in this way?

The last data is longer than the first data as follows:

Mod.	11	12	13	14	21	22	23	24	31	32
Δl (mm)	0.10	0.76	0.08	0.50	0.25	0.23	0.28	0.20	-0.43	-0.05
Mod.	33	34	41	42	43	44	51	52	53	54
Δl (mm)	-0.35	0.00	0.10	0.13	0.15	-0.23	0.28	0.28	0.22	0.51
Mod.	61	62	63	64	71	72	73	74	Σ	
Δl (mm)	0.41	0.31	0.18	0.25	0.28	0.18	0.15	0.20	3.28	

The last data of module lengths are shorter than the designed values as follows:

Mod.	1	2	3	4	5	6	7
Δl (mm)	-1.81	-1.68	-2.14	-4.75	-1.65	-1.69	-0.49

The design total length from the entrance of Mod.1 to the exit of Mod.7 is 59.57922 m. The last given value is 59.561476 m. Thus the survey value is 17.74 mm shorter than the design value.

The beam axis of linac is not exactly placed on the survey axis of "north" or "y-axis". This makes much troublesome in measurement and calculation of the beam line center. The design deviation angle is 18.2"; the measured angle according to the abssica of the exit of Tank-5 and Mod.7 is 16.7".

The present measurement method, e.g. using a long rule to measure the longitudinal dimension and using the outside reference points to determine the internal physical center etc. may also result in some errors. Except the above systematic errors, there are some confusion about the reference points (e.g. downsteam and upstream etc.) and occasional mistakes. After correction several times, it is hoped that most mistakes have been corrected.

All the above results and discussion may mention us that some possible errors may exist which are much larger than the requirement to order of magnitude. The effect of these errors on the Δt and phase scanning measurement needs to be studied.

5 The Suggested Physical Dimensions

All the data given in this material are based on the last values, which are the closest to the design values.

Fig.1 shows the dimensions of the transition section mainly used for calculating the beam dynamic and emittance (transverse and longitudinal) measurement.

Fig.2 shows the dimensions used for Δt and phase scanning measurement. According to the results the suggested data which should be used in Δt measurement program are as follows:

Module	Detector	$D1$	Detector	$D2$
1	WC14	61.97	WC24	7524.83
2	WC24	63.04	WC34	8137.47
3	WC34	65.78	WC54	17813.73
4	WC44	69.08	WC64	18701.51
5	WC54	70.20	BPM74	20043.92
6	WC64	72.77	BPM3	14987.58
7	BPM74	634.63	BPM3	4502.35

The data for phase scanning are as follows:

Module	Detector	$D1$	Detector	$D2$	DAB
Buncher	WC14	8648.76	WC24	16173.59	1360.91
1	WC14	61.97	WC24	7586.80	6570.89
2	WC24	63.04	WC34	8200.51	7239.72
3	WC34	65.78	WC44	8736.68	7824.86
4	WC44	69.08	WC54	9211.91	8335.35
5	WC54	70.20	WC64	9628.89	8789.55
6	WC64	72.77	BPM74	10558.0	9186.81
7	BPM74	634.63			9539.41

Fig.3 shows the dimensions for 400 MeV measurement line.

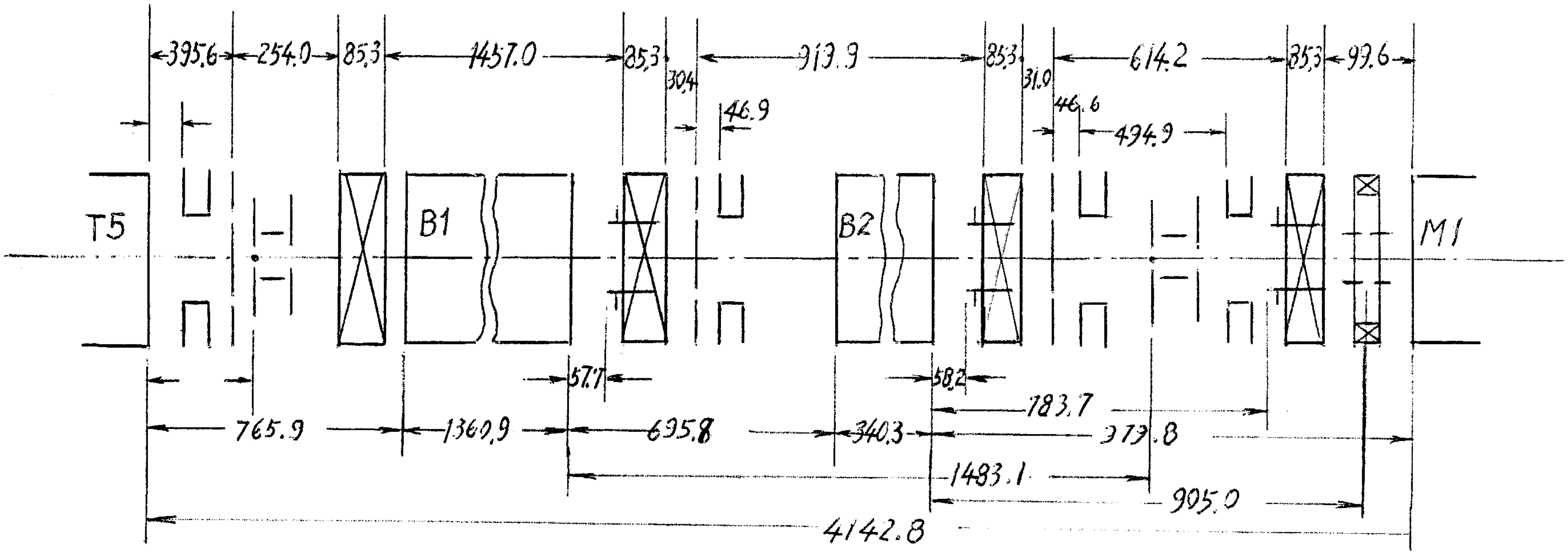

Figure 1: The physical dimension of the transition section.

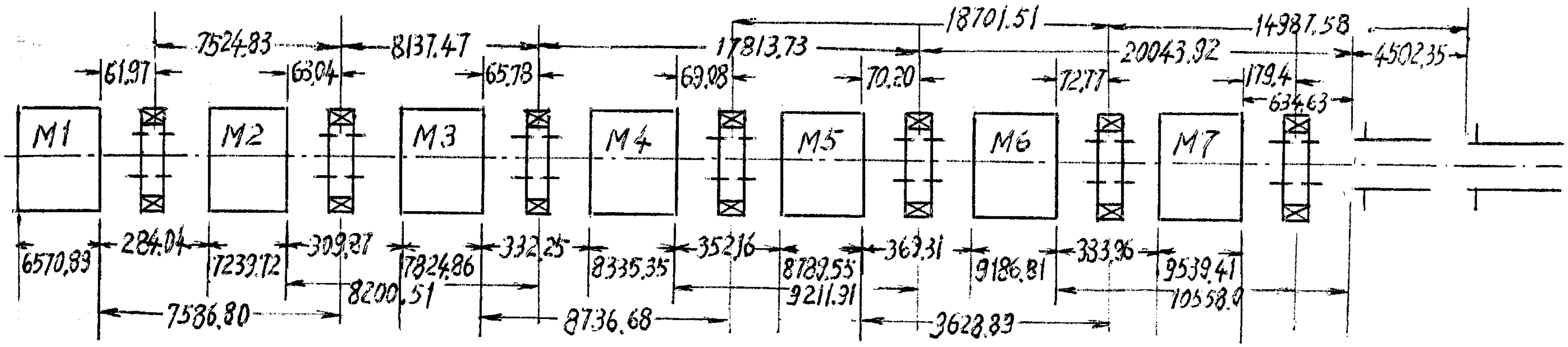

Figure 2: The physical dimension for Δt and phase scanning measurement.

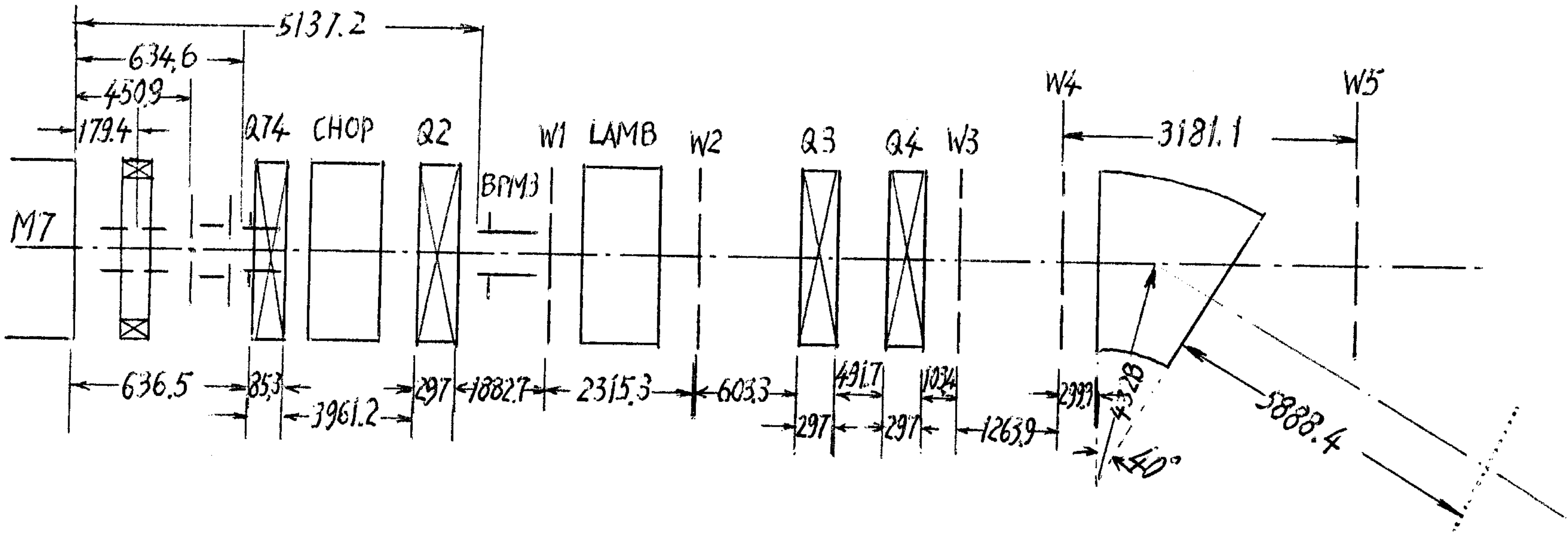

Figure 3: The physical dimension for 400 MeV measurement line.